Innovative technologies for condition assessment and monitoring of concrete

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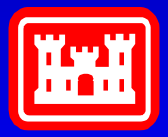


Overview:

- Quick Summary of concrete Non-Destructive Testing
  - Including Findings and Discoveries at ERDC

- Partial plans of the Condition monitoring and assessment work unit

Concrete NDT is needed to:

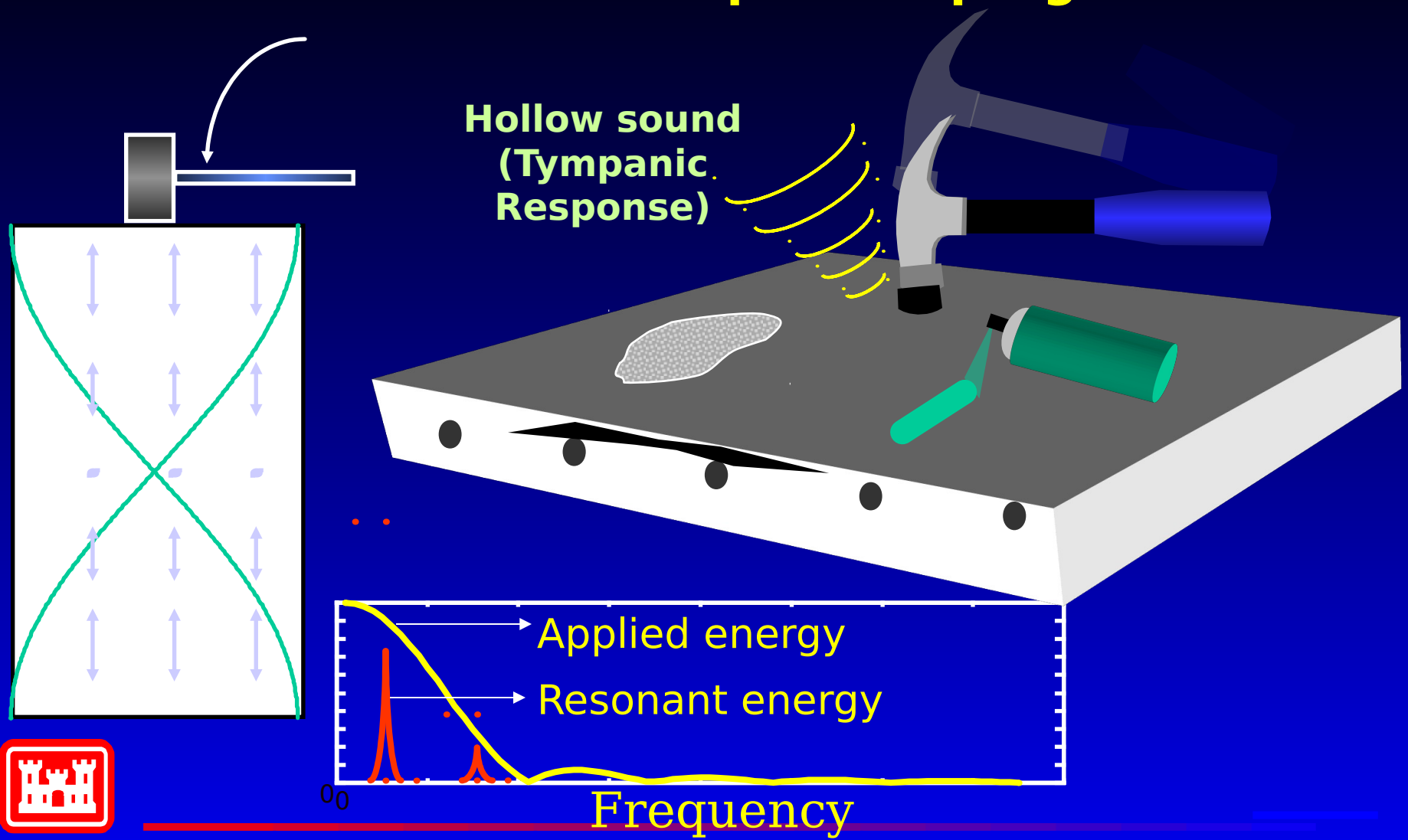
- To detect and/or characterize non-visible conditions
- To gather data that is objective and quantitative
- To facilitate improved destructive testing

What goes wrong with concrete and Why

Condition	Potential Cause
Honeycombing and voids	poor consolidation
Delaminations	corroding rebar (road salt)
Ungrouted tendon ducts	placement problems
Internal cracking	Mechanical stress
Material deterioration	Freeze Thaw damage
Alkali-silica reaction	Chemical reaction

NDT data generally alerts us that something is wrong but it does not always characterize the condition !

Sounding (resonance) and Visual inspection are the standard for most inspection programs



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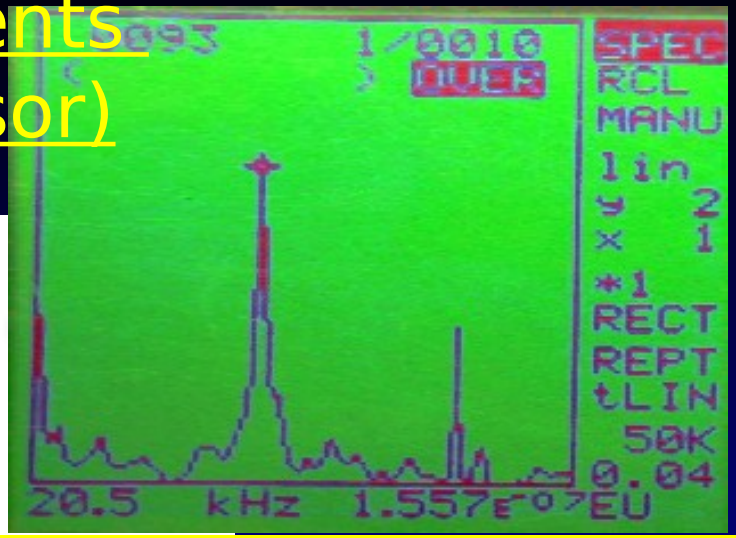
Instrumentation components (digitizer, impactors, sensor)

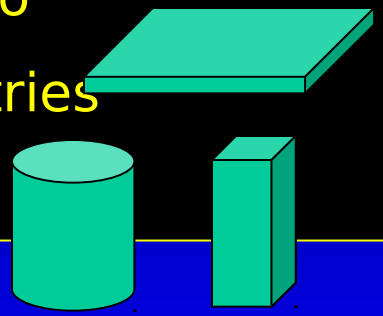


Free Plate Resonance

λ = 2 * thickness = _____
velocity

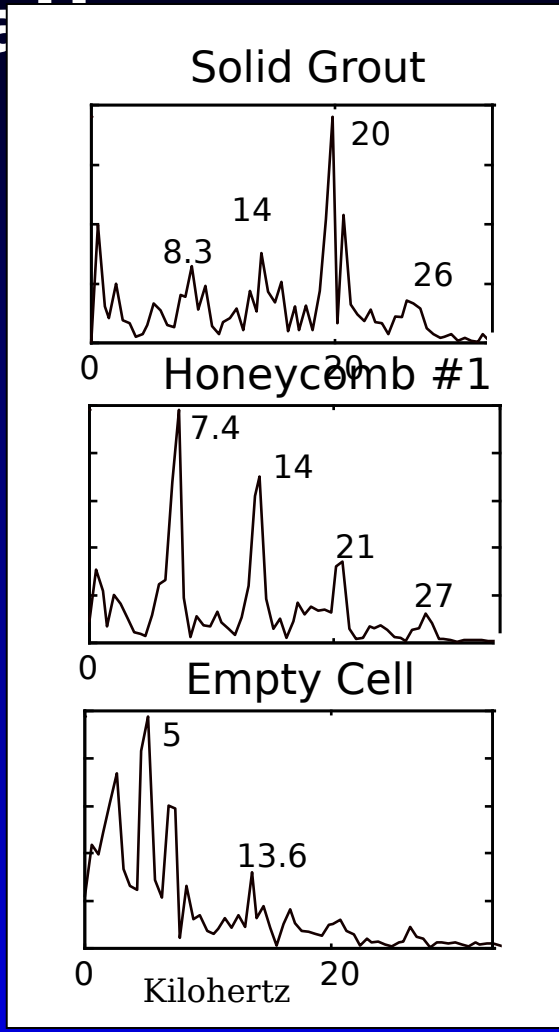
Easily applied to

Simple Geometries



Resonance Based System

Spectral signature characteriza



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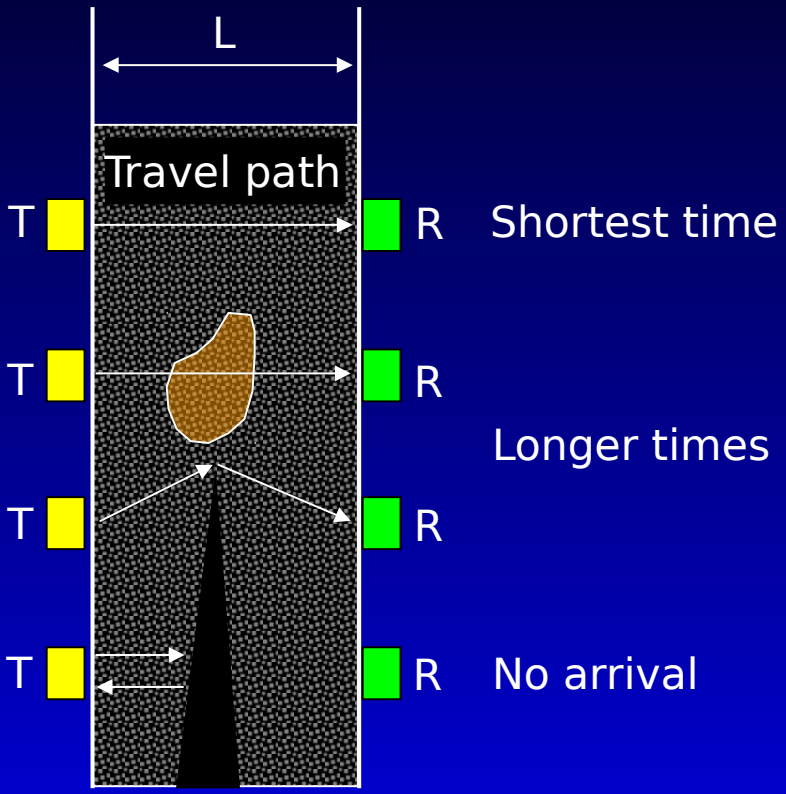
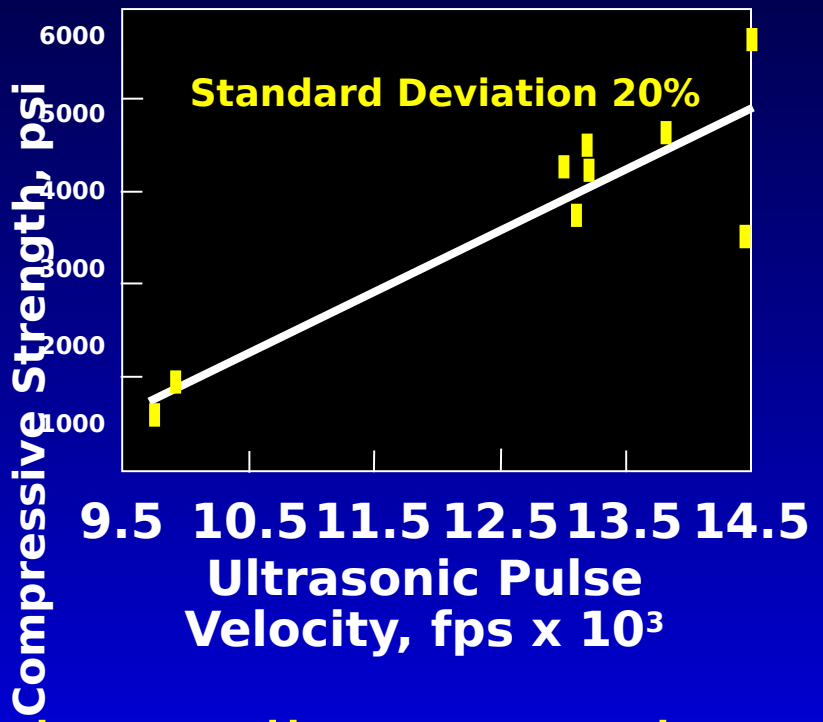
Ultrasonic Pulse Velocity uses high frequency stress waves



Strength-Velocity Correlation



Velocity = distance / time

ERDC findings regarding ultrasonic through transmission

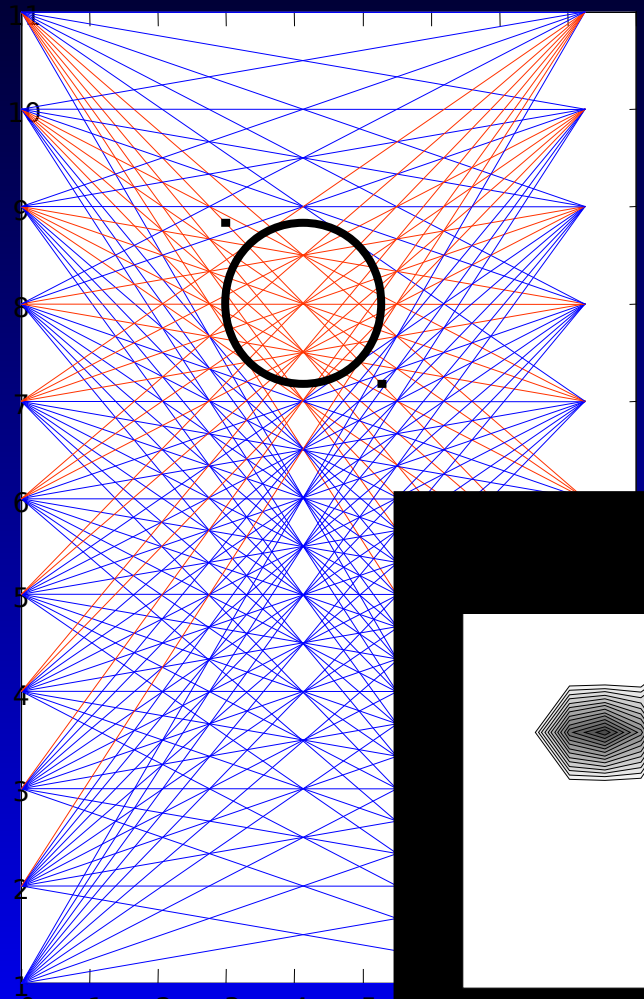
Pulse Amplitude is better than Pulse Velocity for
The detection of flaws such as honeycombing
and parallel cracking

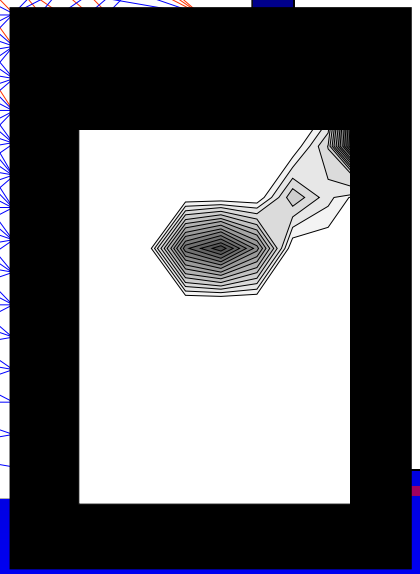
(ERDC Test demonstrated two orders of magnitude)

The oil filled transducer design used in the past
Produce tremendous penetration gains when comb
With modern PZT elements (>66 dB)

Signal processing techniques such as Tomography
Can assist in localizing and characterizing damage
(Diffraction based tomography is still needed)

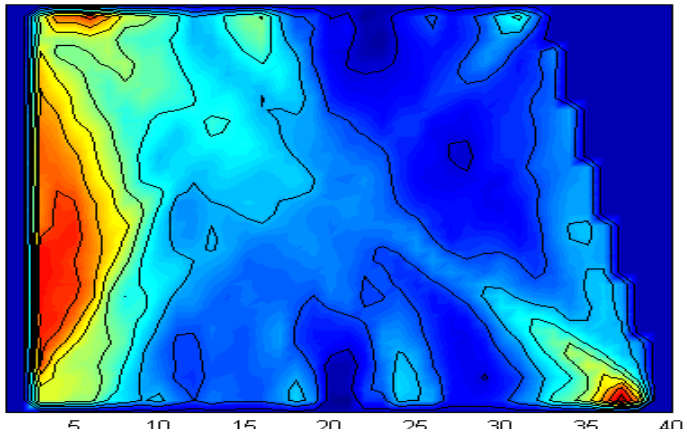
Tomographic imaging will likely advance ture acoustical imaging for concrete (CAT-Sc

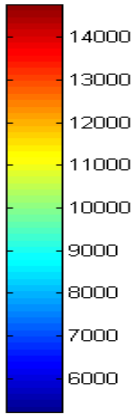




Tomogram From Blast Damaged Specimen

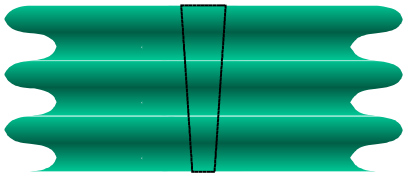
Charge Hole





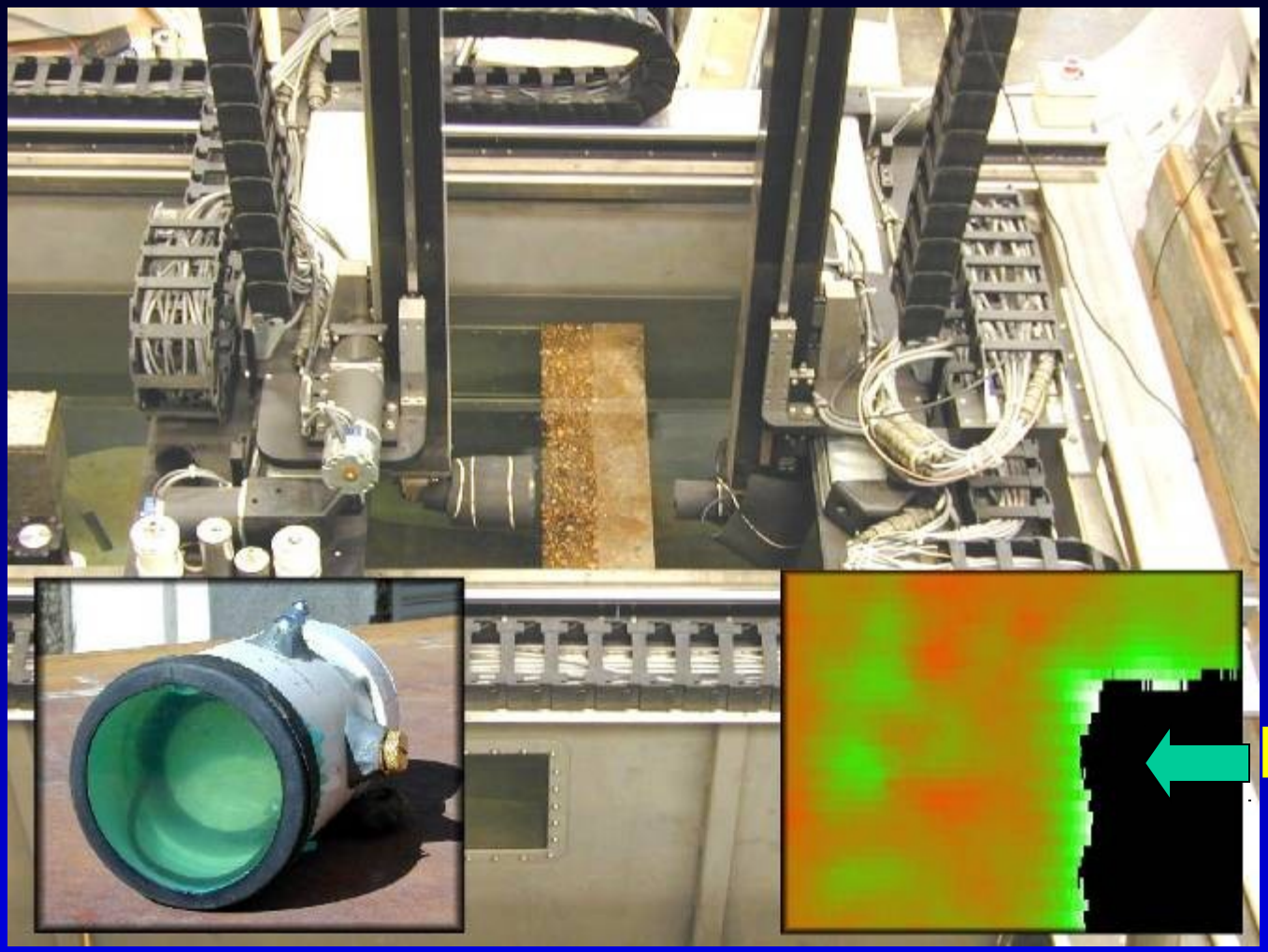
Velocity ft/sec

Sources

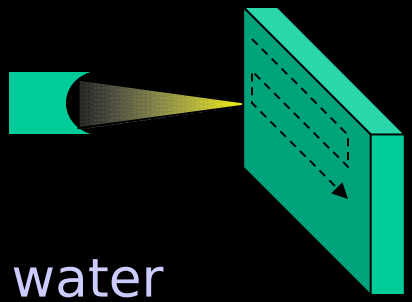


Receivers

Eleven-axis Immersion scanning system being applied for through transmission imaging

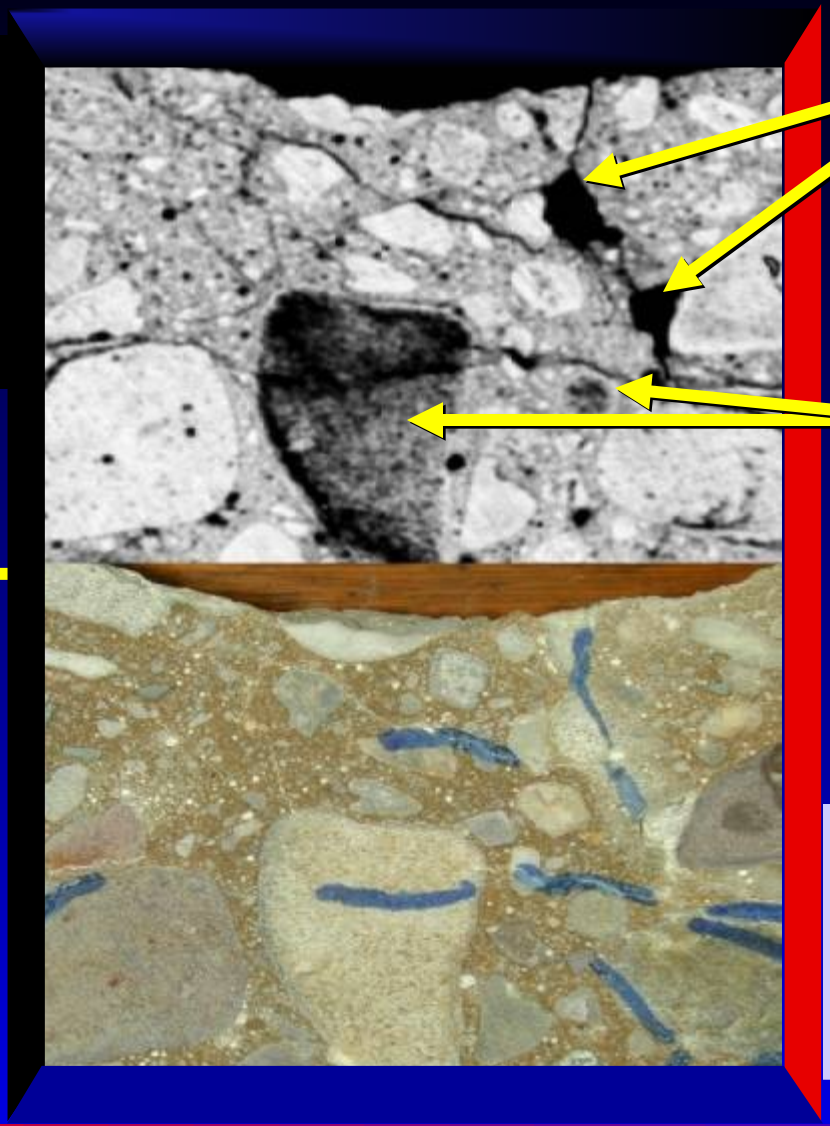


Acoustics are very sensitive to mechanical proper



Ultrasonic Reflection Image

Photograph

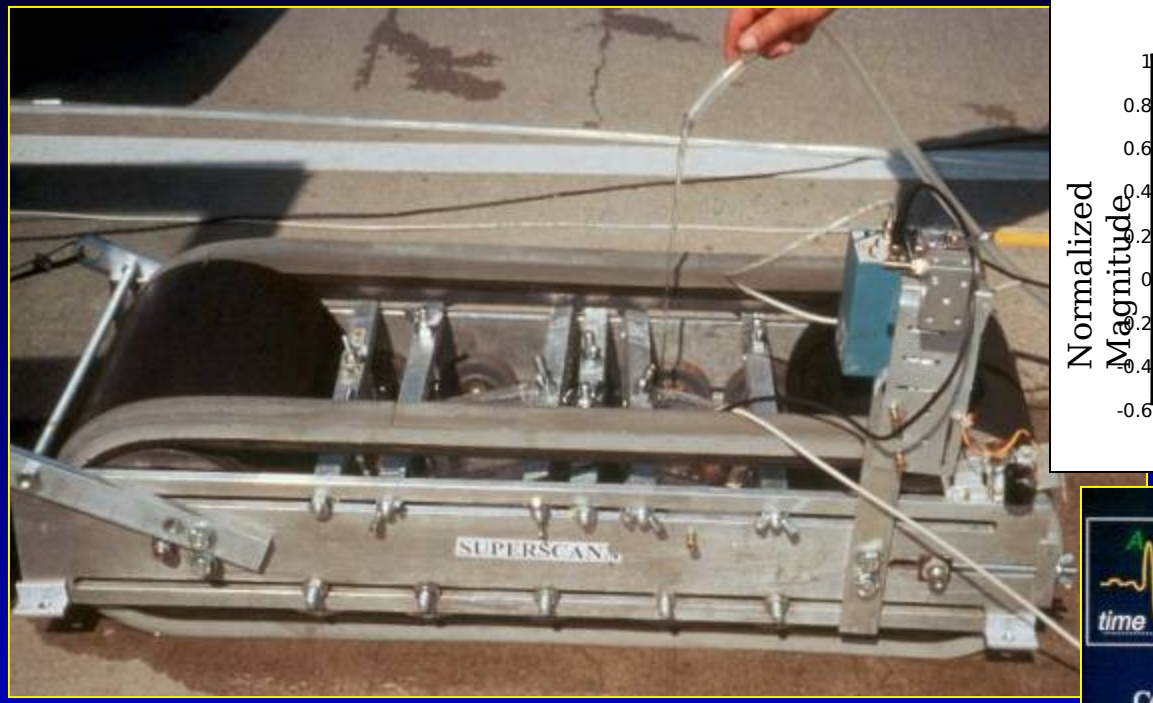


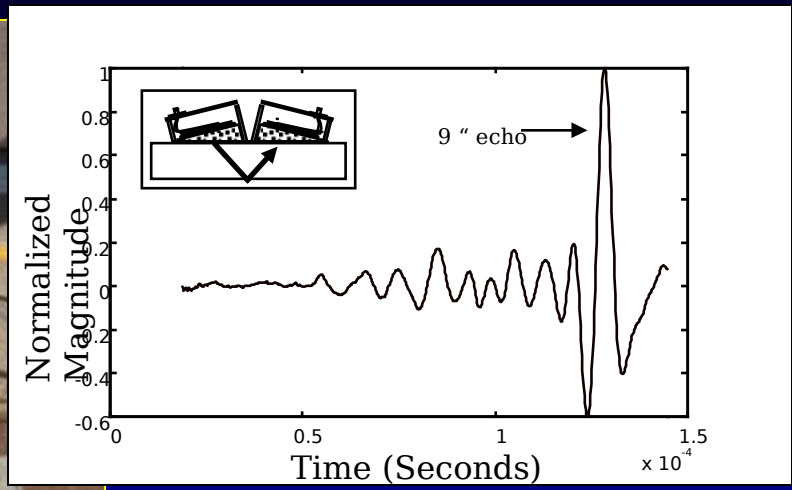
Entrapped Air and microcrack

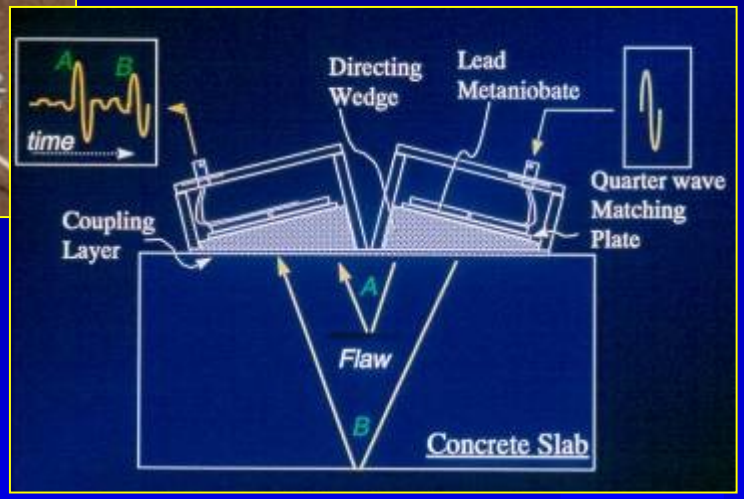
Weak Aggregates detected

This method is Applicable to Cores or Saw-cut specimens

Using specialized equipment it is Possible to make ultrasonic echo measurements and perform Scanning of concrete (non-commercialized technology)







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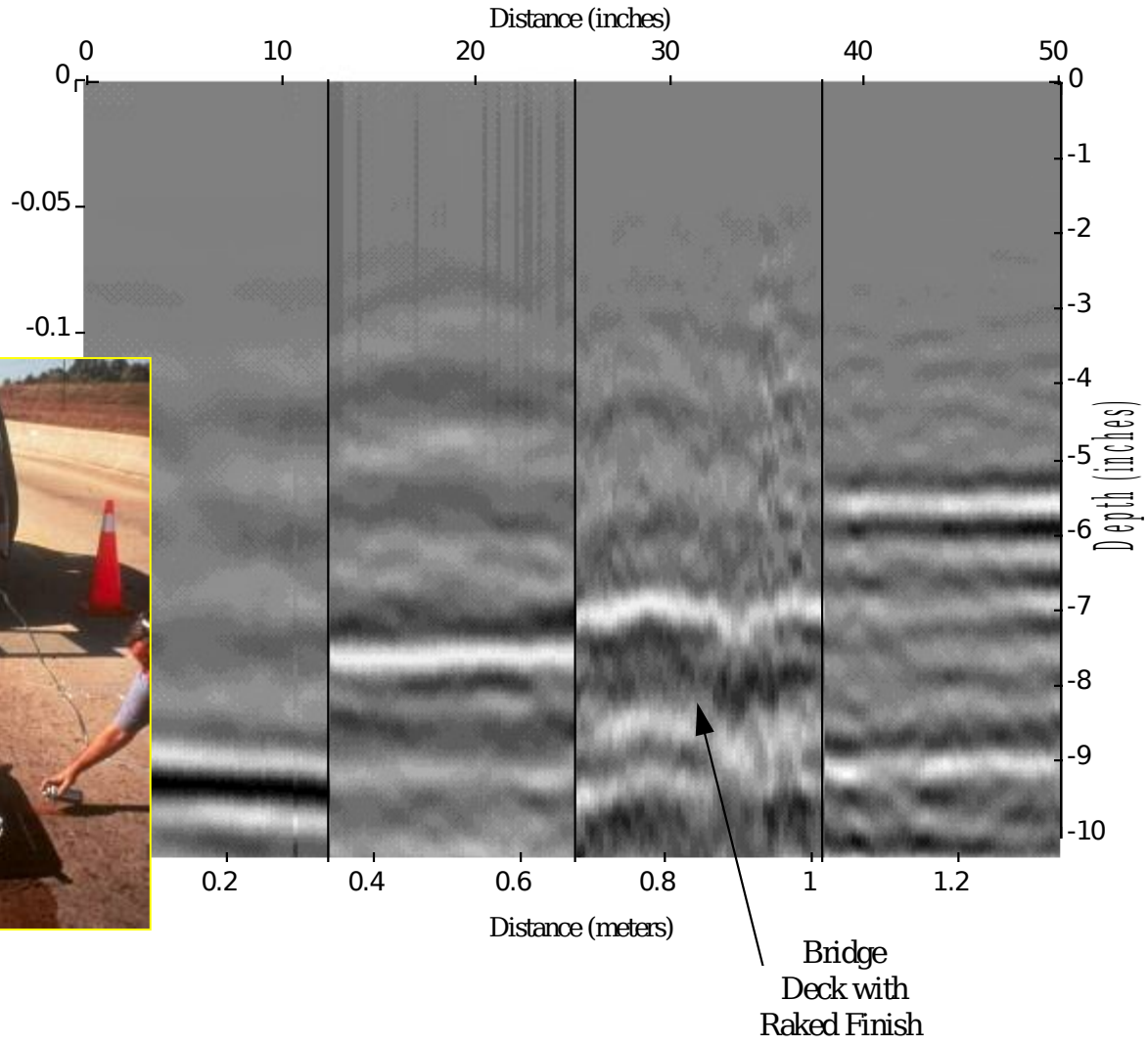
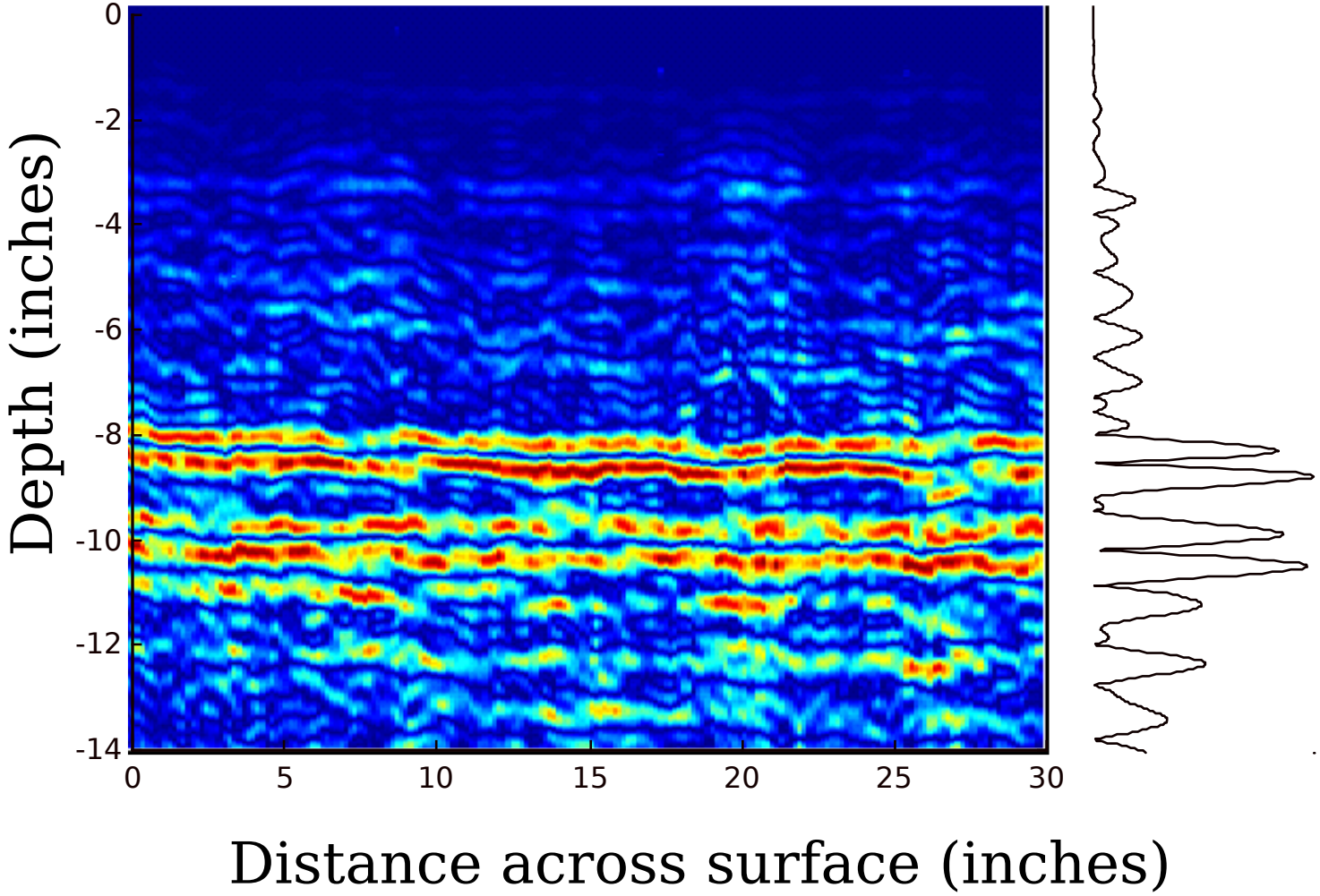
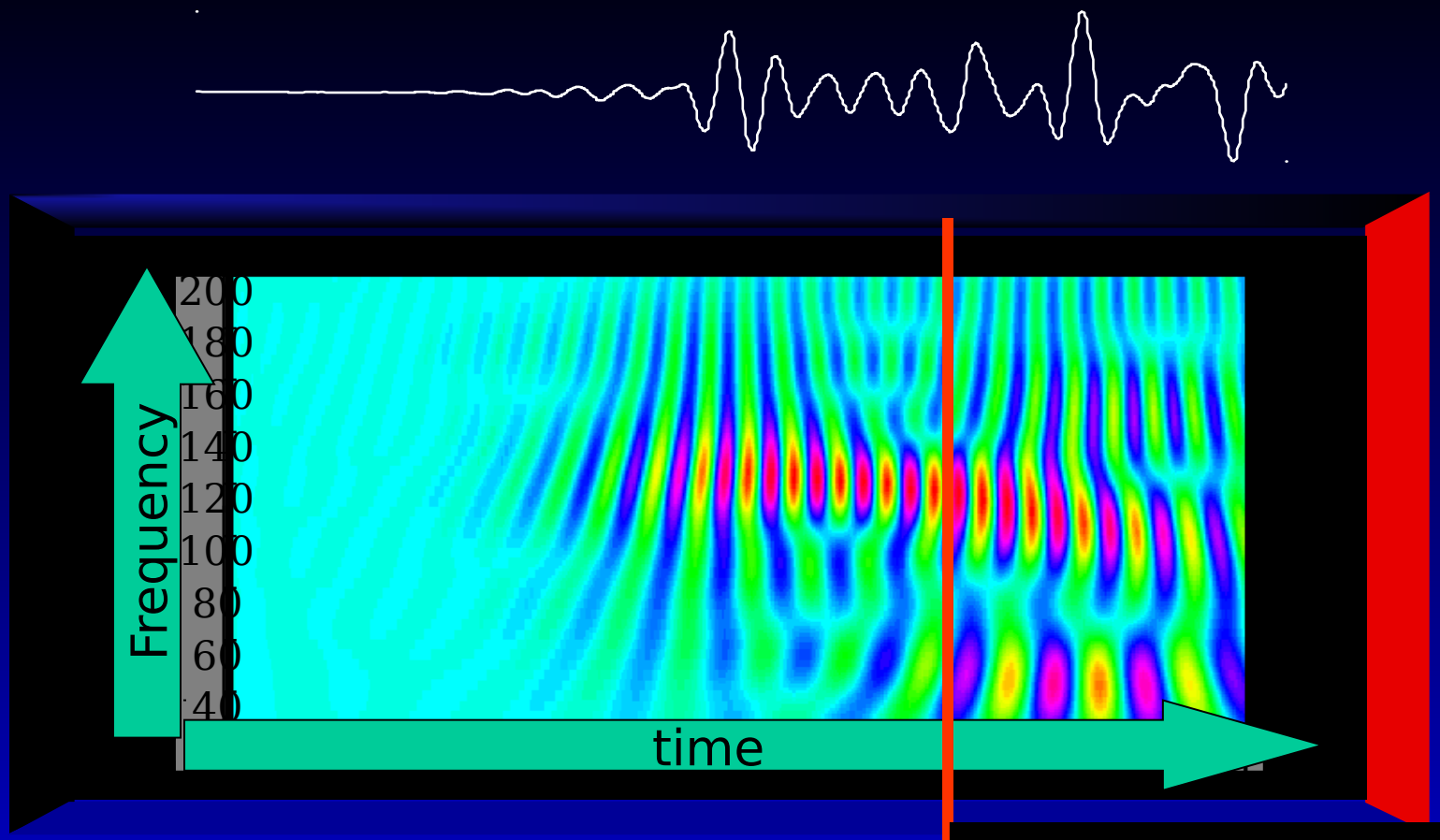
Various thickness scans



Ultrasonic B-Scan of an 8-Inch Concrete Bridge Deck

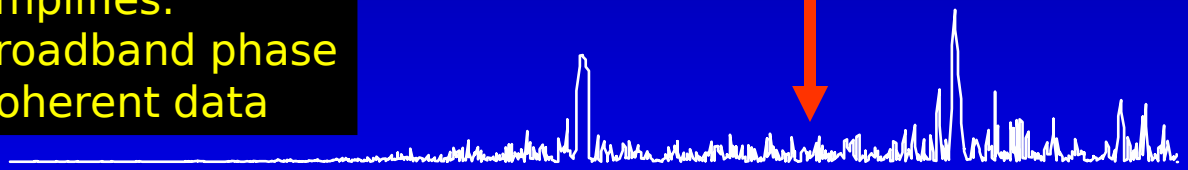


SPLIT SPECTRUM PROCESSING (Non-linear Filtering)



Recombined (minimum abs

Amplifies:
Broadband phase
Coherent data



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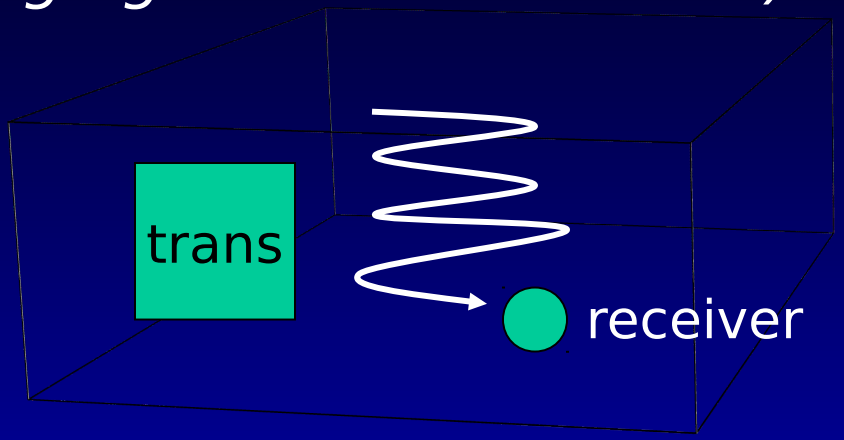
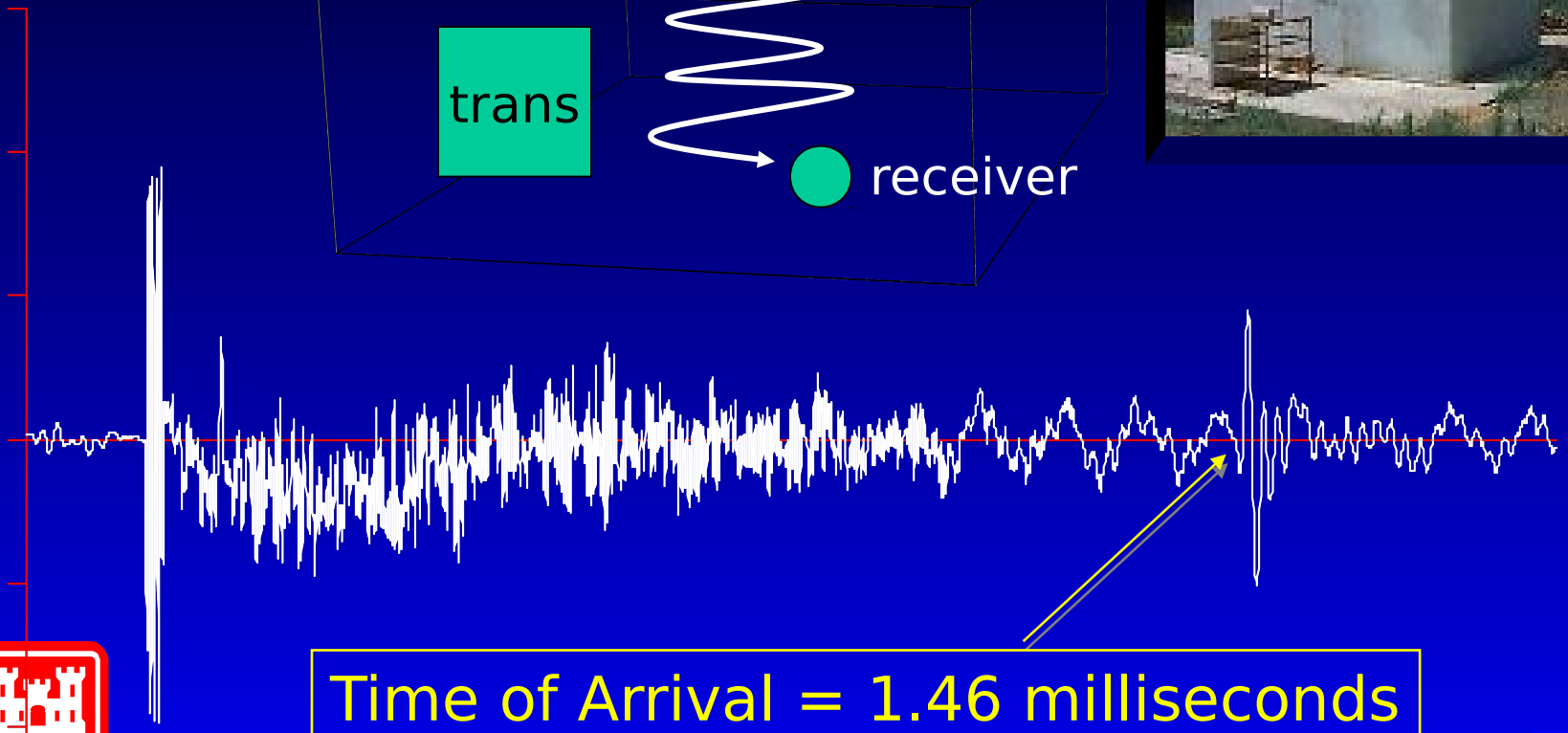
UPE through 10-feet of Concrete By Spatial Averaging Technique

(enhances compressional wave While averaging out surface waves)





Time of Arrival = 1.46 milliseconds

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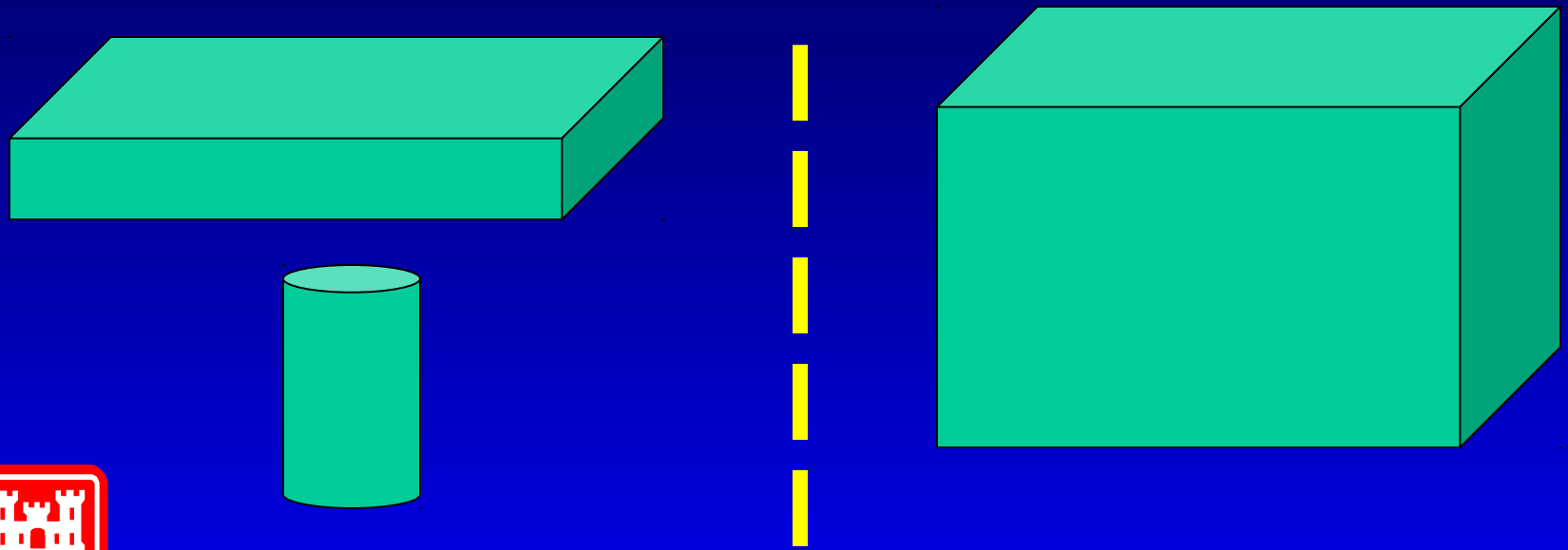
Common Difficulties with testing large concrete structu

a) Lack of Two sided access
b) Backwall Reflecting surface too deep
c) Large Aggregate (scattering ~ wavelength)
d) Surface Deterioration

Conventional structural elements

Mass Concrete



Partial Plan for the Condition monitoring and assessment work unit

- Develop or Examine better tools for site inspectors
  - -Low cost and practical to use
- Evaluate performance of an Instrumented core rig
  - - for determining deteriorated concrete strength as a function of depth
- Perform better inspection of cores using NDT prior to DT
  - - Evaluate non-linear resonance spectroscopy
  - -Scanned echo and through transmission on cores
  - -Evaluate Tensile testing as damage indicator
- Develop / Evaluate sensor package to be grouted into core hole
  - - measurement along key axis using proven technology

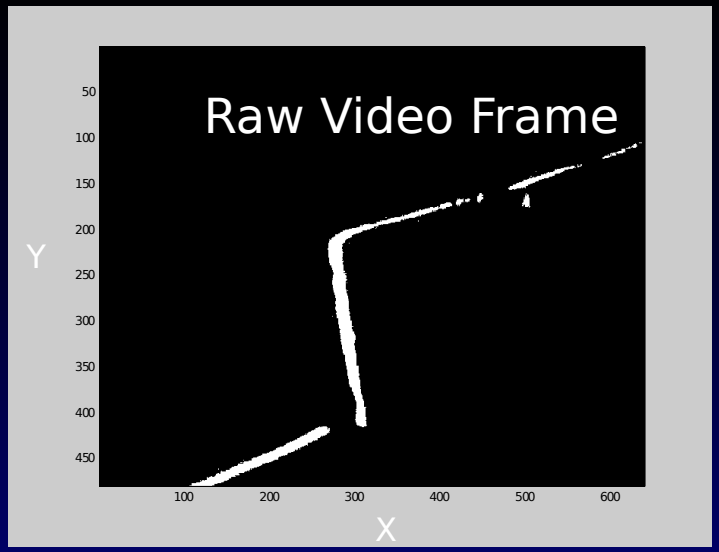
PI: Dr. Stan Woodson

Need tools for improved Quantification of surface damage/deterioration

Approx 4 inches Deep

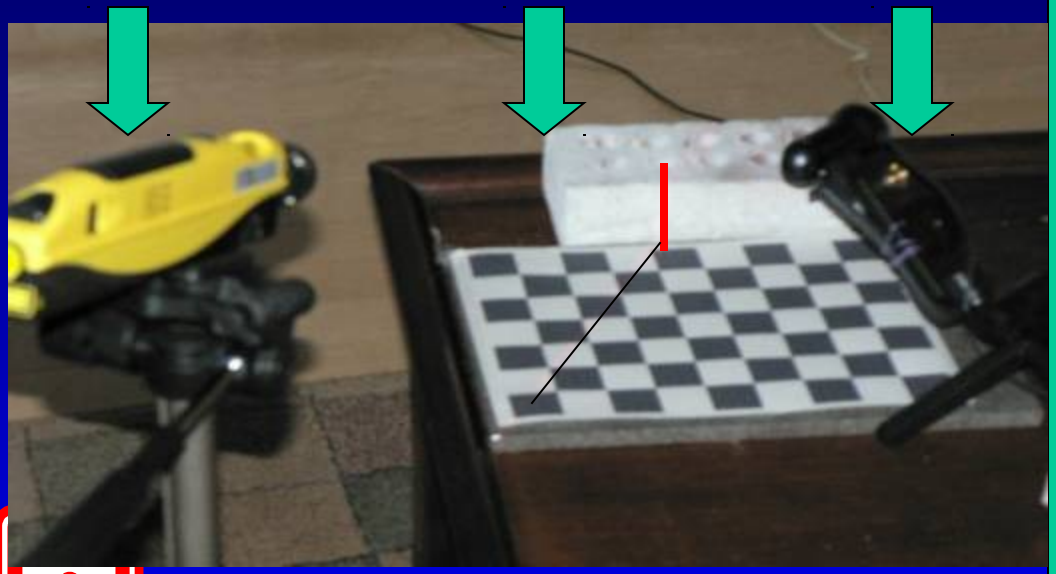
Low Cost Topography

System Setup and Preliminary Data



Processing steps:
Adjust camera settings to show only laser beam
Collect video during target translation (fixed camera and light
For each frame and Y position determine x position of beam ec
Generate composite of x positions (below: y-axis is Frame coun
Remove linear trends

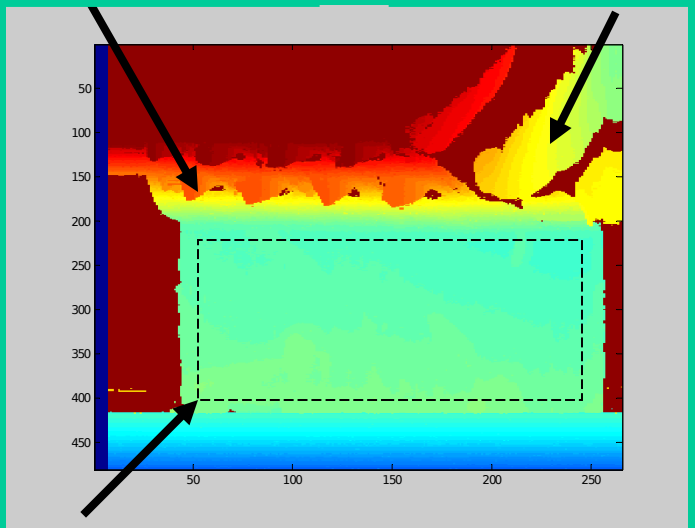
Line Laser target USB cam



Composite data from Frame integration

Holes in Top of brick

Fingers (moving target)



Final Image plane

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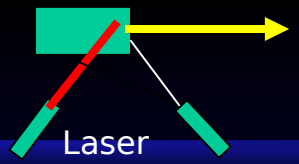
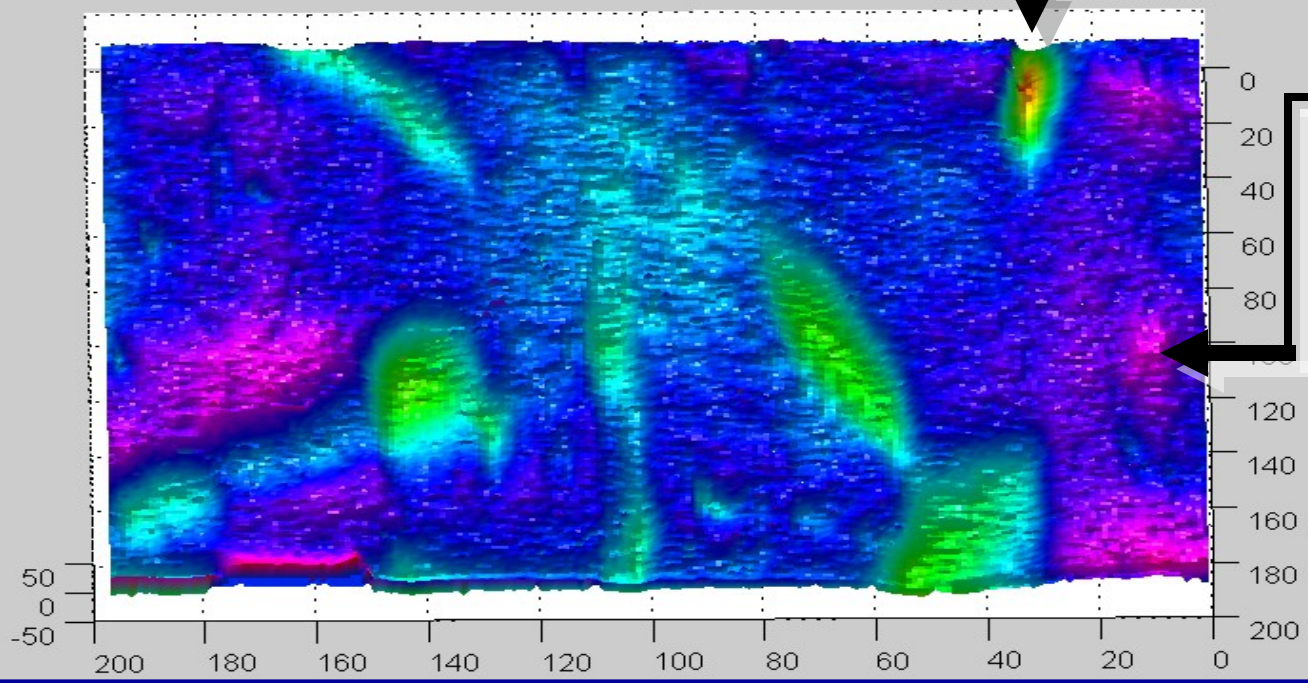
Enginee



Global Minimum



High points detected

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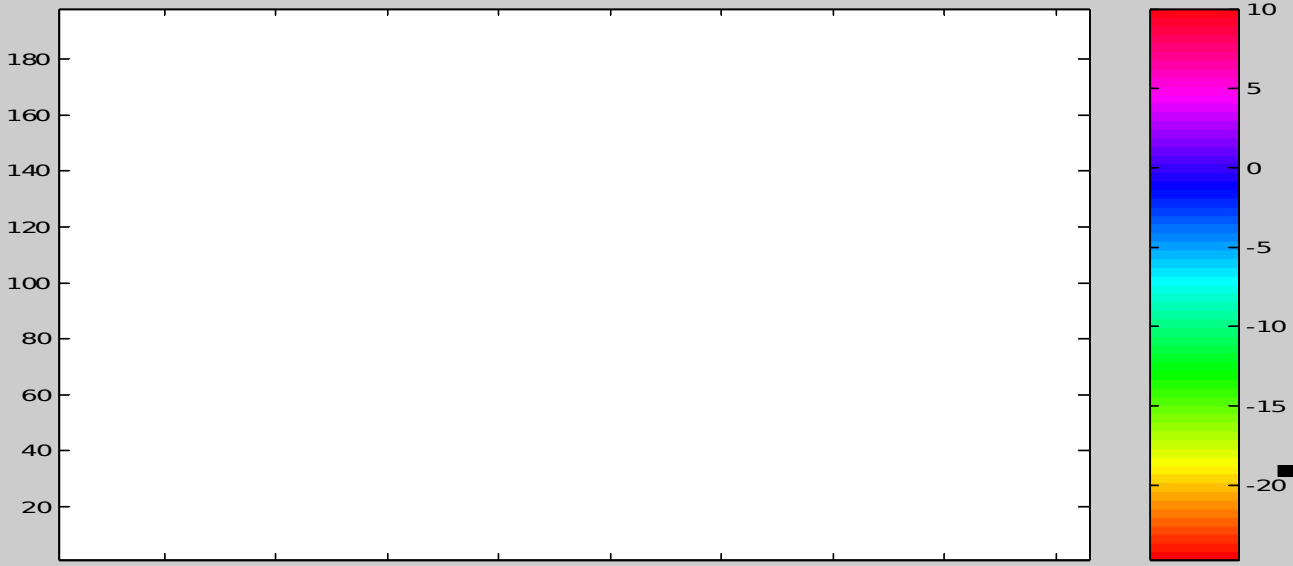
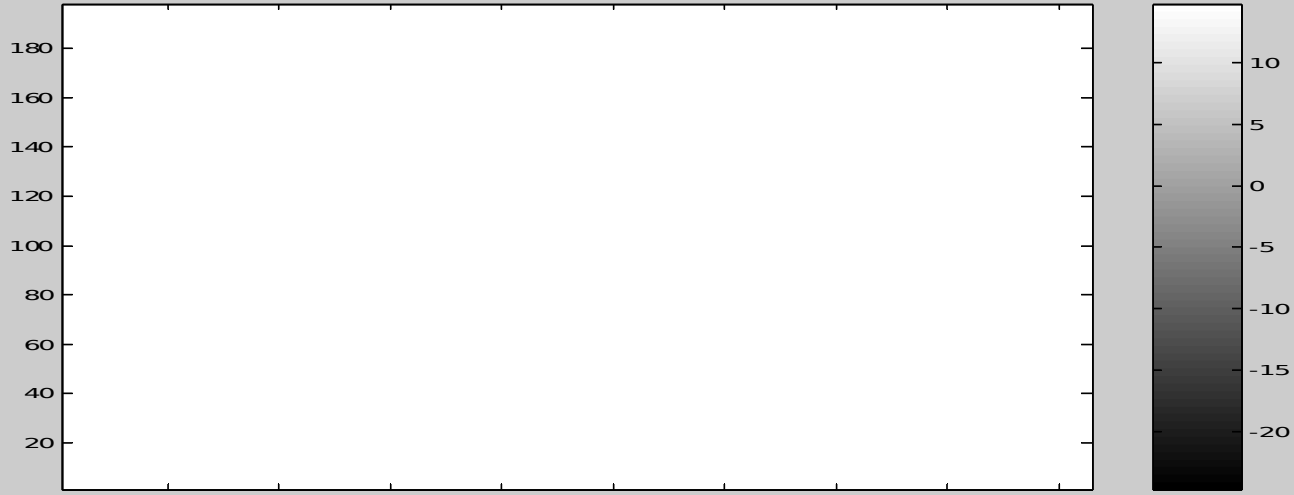
Alternate Visualizations



-1/8 inch



velopment
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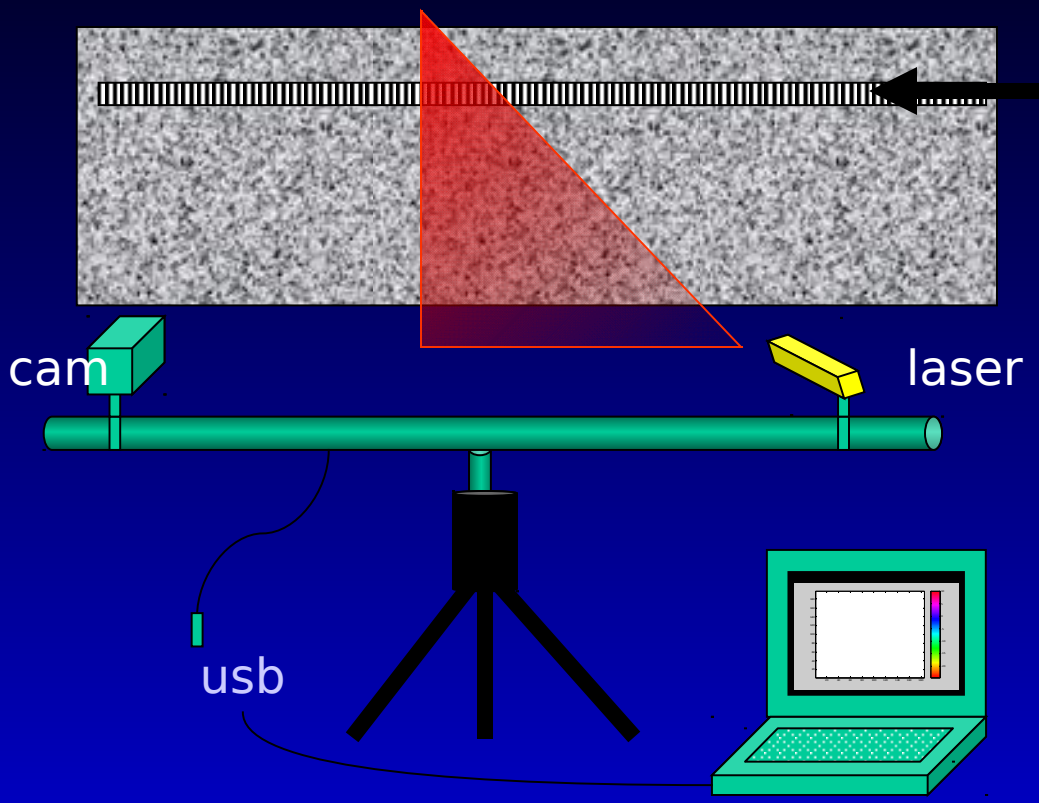
Conceptualized System



Objectives:

Determine material topography

Referenced for chronological analysis

Determine out of plane displacements

Pan Head (valve actuator)

Fractured Concrete Surface
(splitting Tensile)

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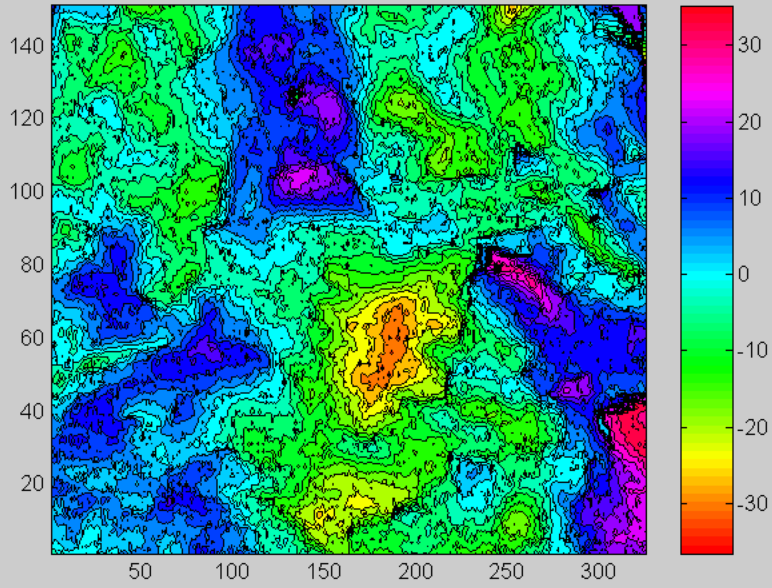
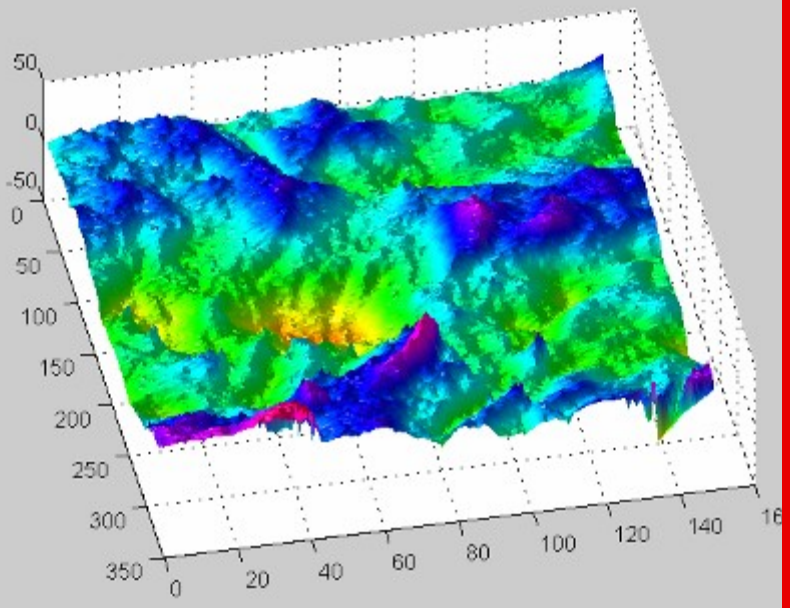




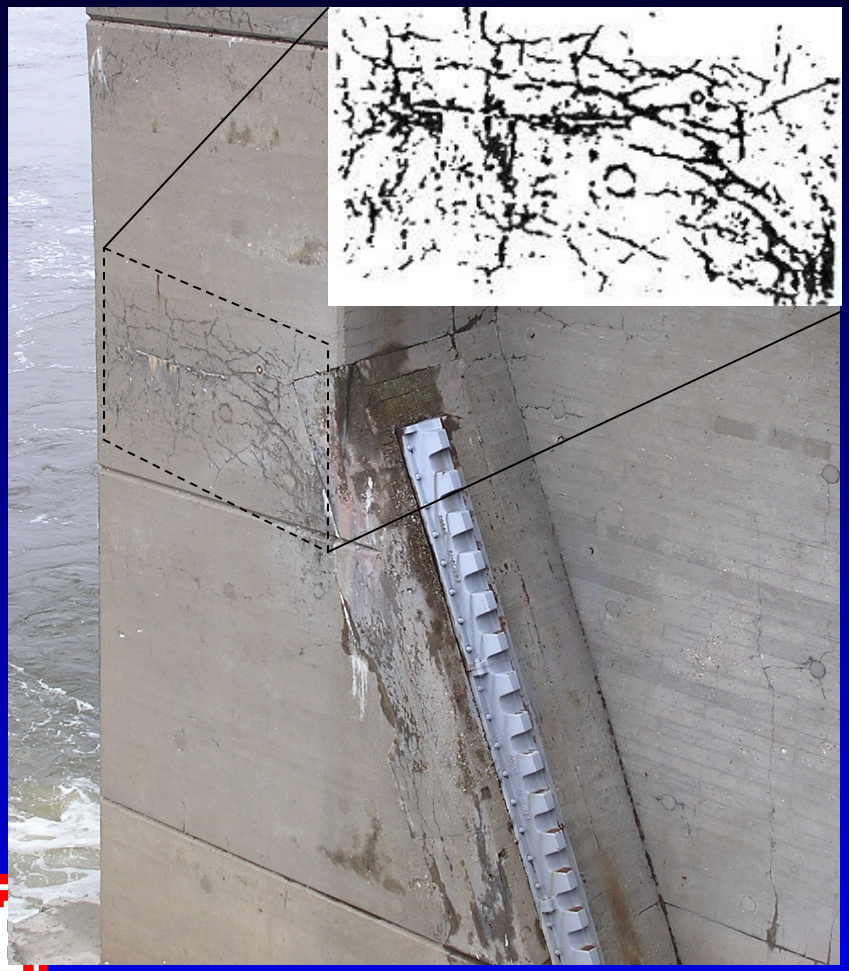
Related plans include:

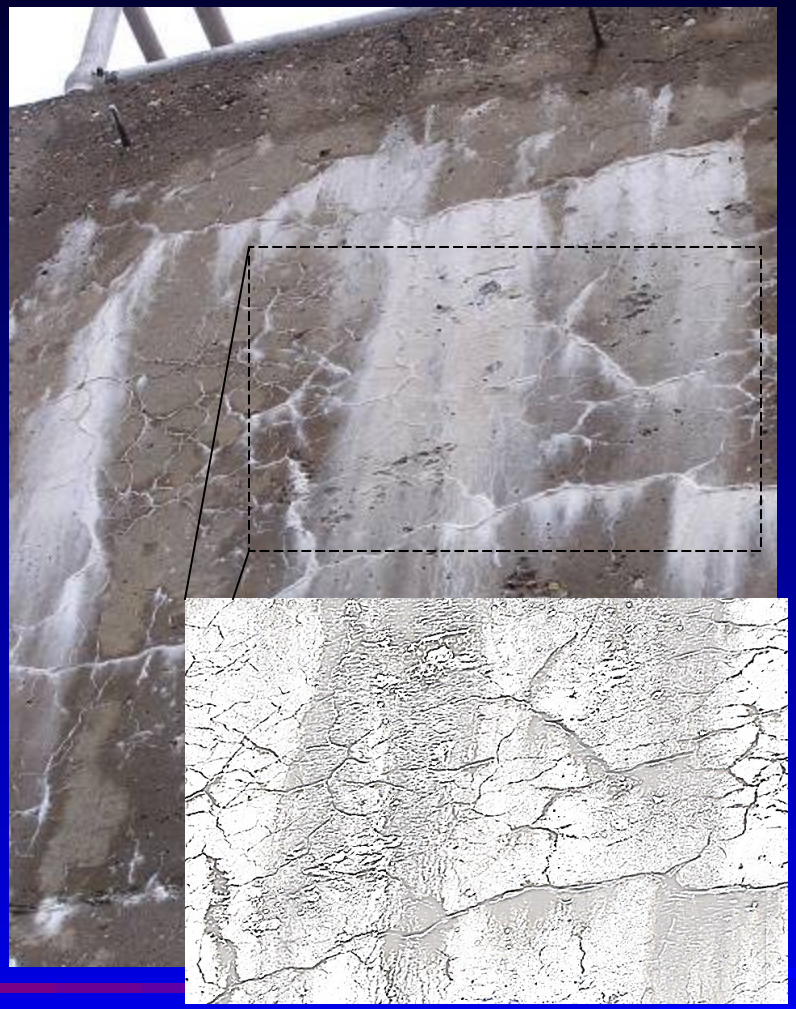
Practical methods to mosaic detailed 2d and 3d images

Imaging and processing methods to improve crack mappin

- Show small cracks
- Determine crack growth between inspections

Application of Standard Image Processing operations to better show damage





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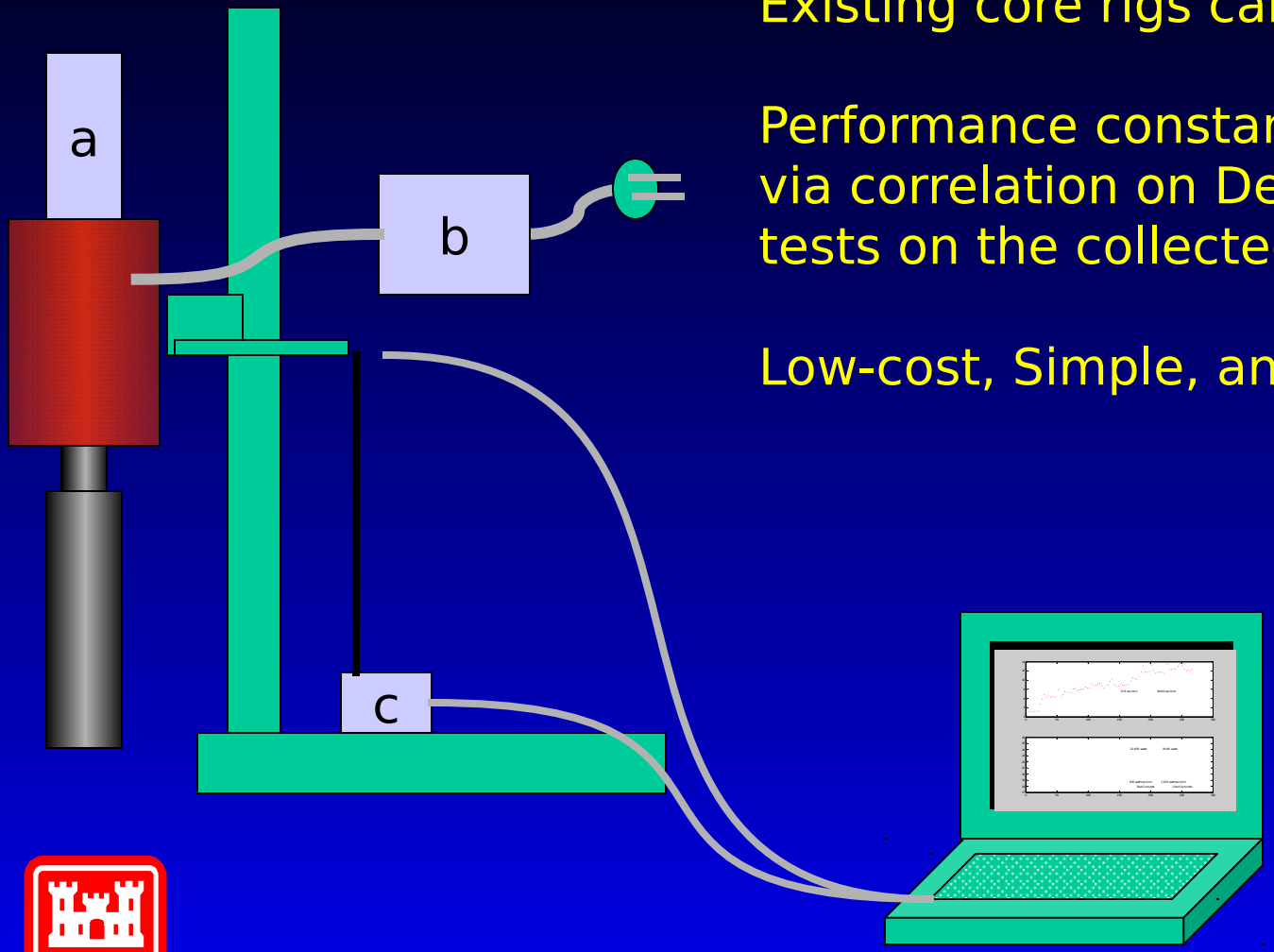
Instrumented Core Rig (energy consumption ~ concrete strength)



Existing core rigs can be retrofited in ½

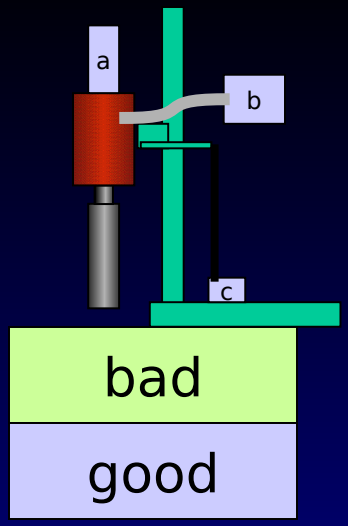
Performance constantly improves via correlation on Destructive tests on the collected cores

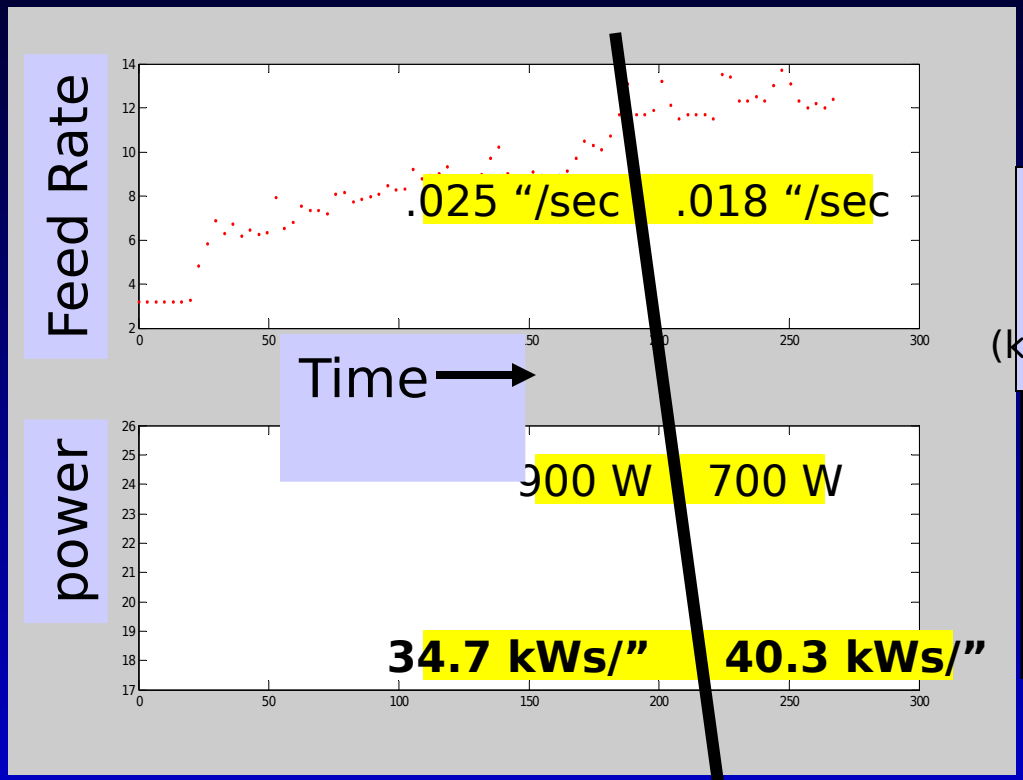
Low-cost, Simple, and robust concept

Parts:

a Weight
b Real power Meter
c string-pot

Initial data from First Prototype System





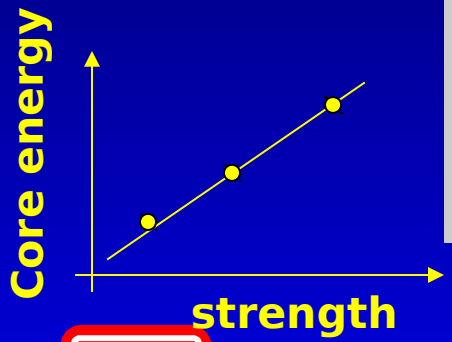
34749.035 bad

40322.581 good

Composite
Is product

(kWatt x seconds)/ inch

Initial results show
Excellent
agreement
With destructive
test
(linear fit)



Bad material
(F&T damage)

Good material

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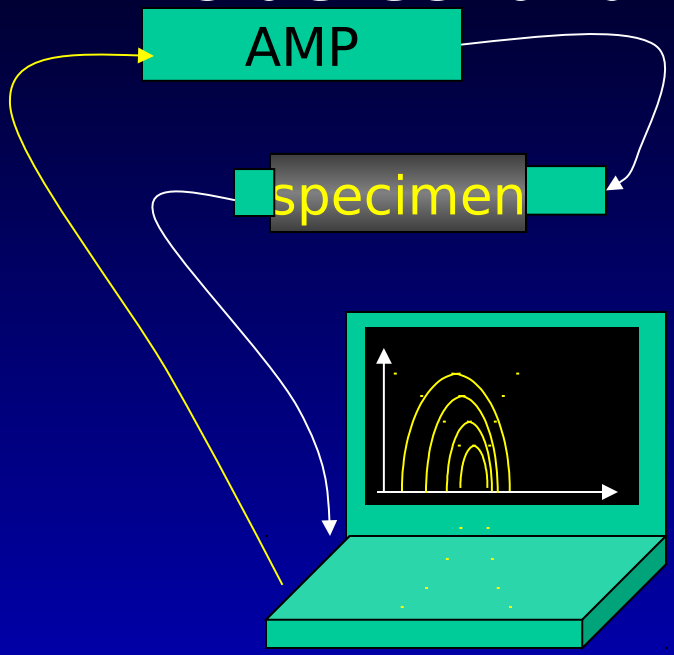
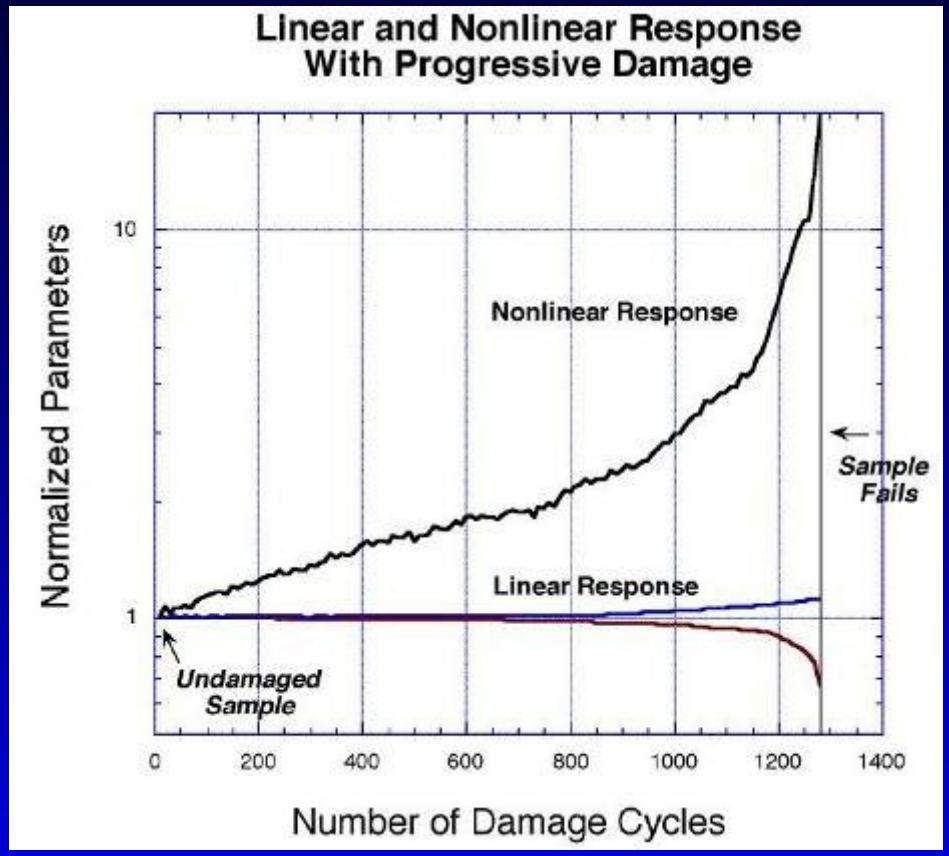
Non-linear resonance spectroscopy

To detect and quantify microscopic damage





Correlated to
Destructive test data
To determine
Structural Significane

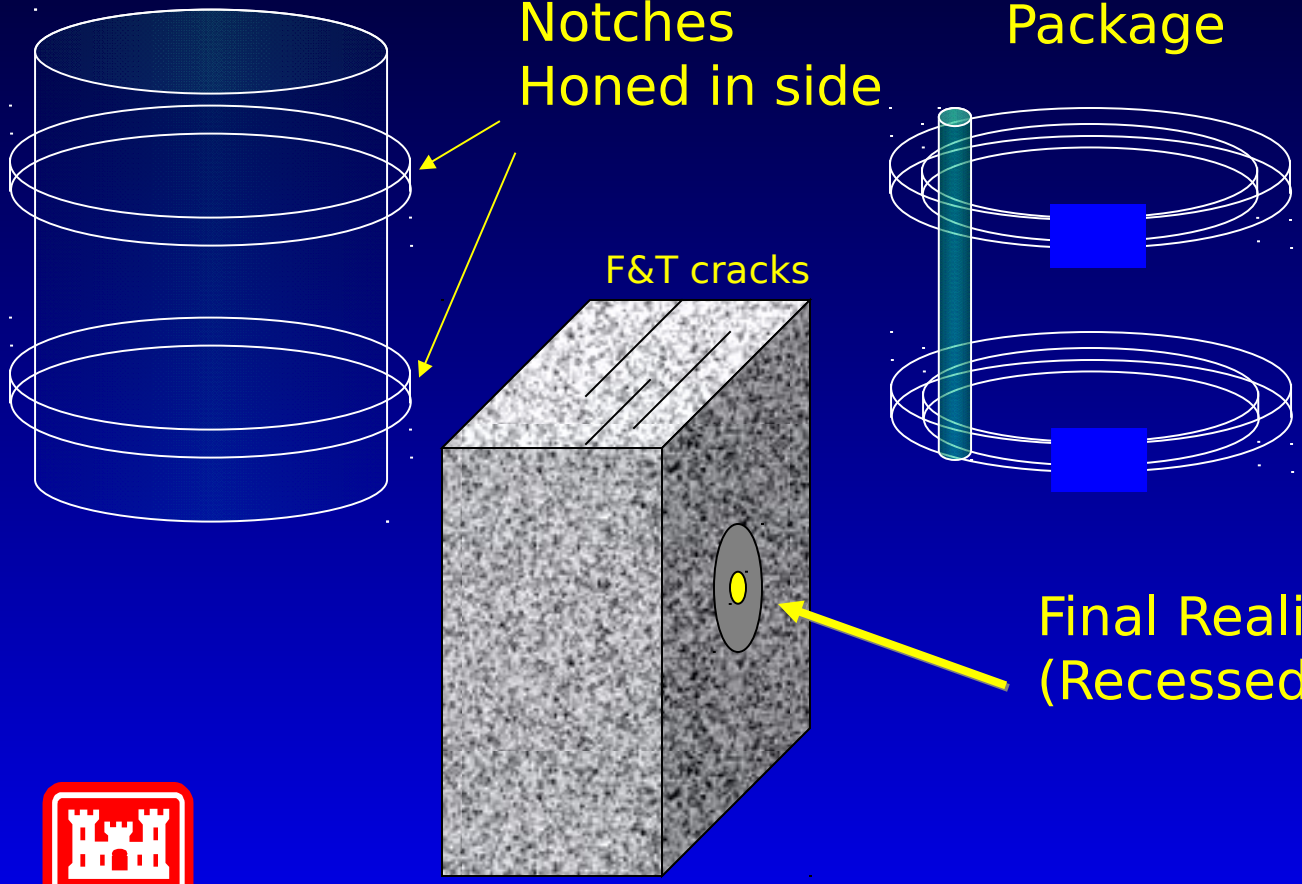
Instrumentation grouted into core hole

Core hole

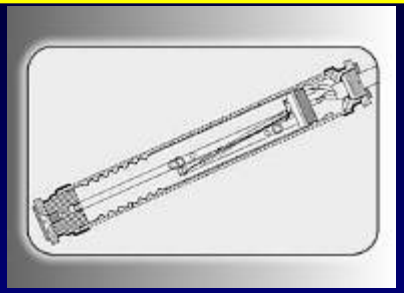
Notches
Honed in side

Sensor
Package

F&T cracks



Candidate Sensor:
Carlson Strain meter



Objective:
Get the sensor
Oriented in the
Right Dimension

Final Realization
(Recessed electrical terminals)

Questions